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METHOD OF ANISOTROPY DETERMINATION OF LARGE-SCALE IONOSPHERE IRREGULARITIES BY THE RADIOASTRONOMICAL METHOD

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SUMMARY

A method is described for the determination of anisotropy of large-scale ionosphere irregularities according to the results of measurements of irregular radioastronomical refraction in three directions.

General effective formulas are obtained for the computation of parameters of the anisotropy ellipse and of its orientation.

author

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We shall consider the problem of determination of anisotropy of large-scale ionospheric irregularities by the results of simultaneous measurement with the help of radiointerferometers of the irregular radioastronomical refraction R_H in three directions. The geometrical thickness L_0 of the layer responsible for the oscillation of refraction and the amplitude of its disturbances h_0 are assumed to be small by comparison with the dimensions d of the irregularity in the plane of the layer, the perturbation function ψ being a smooth periodical function.

Obtained earlier [1] was the dependence of the vertical component $R^{\text{в}}_{\text{н макс}}$ * on the zenithal angle z of the observed source for two irregularity models: the lenticular (1) and the sinusoidal (2),

$$R^{\text{в}}_{\text{н макс}} = 2\pi\Delta h_0/d_{\text{л}} \cos^2\alpha_0, \tag{1}$$

$$R^{\text{в}}_{\text{н макс}} = L_0\Delta h_0\psi''_{\text{макс}} \sin\alpha_0/\cos^3\alpha_0, \tag{2}$$

where α_0 is the angle between the direction to the source (by the ray) and the normal to the layer, wh reupon $\sin\alpha_0 = [R/(R+h)]\sin z$, R being the radius of the Earth, and h the altitude of the layer. Utilizing the measured values of $R^{\text{в}}_{\text{н макс}}$, it is easy to obtain from (1) and (2) the dimensions (periods) of the irregularities for the two indicated models in the plane of the azimuthal circumference of radiointerferemeter's base. Taking into account that $\psi'' = 4\pi^2/d_c^2$, we have

* stands in text and formulas for $R^{V}_{H\,max}$

$$d_{\text{л}} = \frac{2\pi\Delta h_0}{\cos^2\alpha_0} R_{\text{н макс}}^{\text{в}-1}, \quad (1')$$

$$d_{\text{с}} = 2\pi(L_0\Delta h_0 \sin\alpha_0/\cos^3\alpha_0)^{1/2} R_{\text{н макс}}^{\text{в}-1/2}, \quad (2')$$

(1') and (2') are applicable for the computation of dimensions only in the azimuthal plane of the base. It is obvious, however, that for an arbitrary measurement plane M, passing through the ray and the base, the dependence of d on $R_{H\ max}$ has the same form:

$$d_{\text{л}} = \frac{2\pi\Delta h}{\cos^2\alpha} R_{\text{н макс}}^{-1}, \quad (3)$$

$$d_{\text{с}} = 2\pi(L\Delta h \sin\alpha/\cos^3\alpha)^{1/2} R_{\text{н макс}}^{-1/2}. \quad (4)$$

Here L and Δh are respectively the thickness of the layer and the amplitude of perturbations in the plane M; α is the angle between the ray and the radius of the circle formed by the cross-section by the plane M of the spherical layer containing the irregularities. Let us express L, Δh and α by means of the following parameters: L_0, Δh_0, R, h, and also A, z, respectively the azimuth and the zenithal angle of the source and A_{δ}, θ, the azimuth and the angle of the site of radiointerferometer's base. Let us consider the cross section of the layer and the Earth by the plane M (Fig.1). Here ρ is the radius of the circle formed by the cross section of the Earth; r is that of the layer; l is the distance between the point of observation C and the point of encounter of the ray with the layer S; z' is the zenithal angle of the plane M. Taking into account that $L_0 \ll h$ and $\Delta h_0 \ll h$, we shall write for L and Δh

$$L = L_0/\cos\chi, \quad \Delta h = \Delta h_0/\cos\chi,$$

where

$$\sin\chi = [R/(R+h)]\sin z'.$$

After simple transformations we shall obtain for Δh and $L\Delta h$

$$\Delta h = K(K^2 - \sin^2 z')^{-1/2}\Delta h_0, \quad (5)$$

$$L\Delta h = K^2(K^2 - \sin^2 z')^{-1}L_0\Delta h_0, \quad (6)$$

where

$$K = (R+h)/R.$$

For α we have

$$\cos\alpha = (r^2 + l^2 - \rho^2)/2rl. \quad (7)$$

From the sketch of Fig.1 we find

$$\rho = R\cos z', \quad (8)$$

$$r = R(K^2 - \sin^2 z')^{1/2}, \quad (9)$$

$$l = R[(K^2 - \sin^2 z)^{1/2} - \cos z]. \quad (10)$$

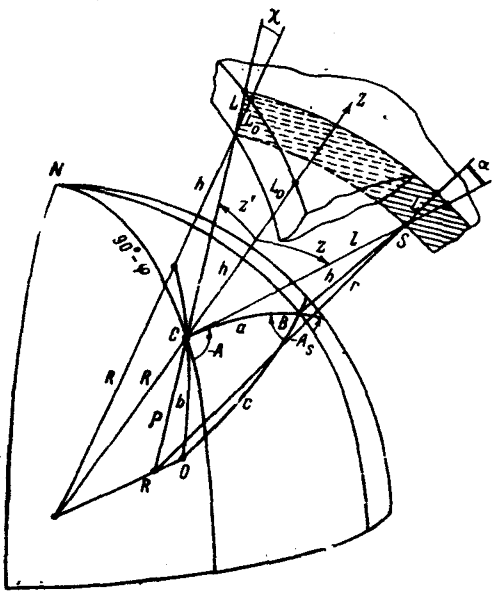

Fig. 1

Substituting (8), (9) and (10) into (7), we obtain after fairly simple transformations

$$\cos\alpha = ((K^2 - \sin^2 z)/(K^2 - \sin^2 z'))^{1/2}. \quad (11)$$

Then, substituting (5) and (11) into (3), (6) and (11) into (4), we shall have for the dimensions of lenticular and sinusoidal irregularities respectively

$$d_л \sim (K^2 - \sin^2 z') R^{-1}_{\text{н макс}}, \tag{12}$$

$$d_c \sim (\sin^2 z - \sin^2 z')^{1/4} R^{-1/2}_{\text{н макс}}. \tag{13}$$

The irregularities' anisotropy ellipse is determined by their relative dimensions in three directions, which allows to drop in (12) and (13) the factors not depending on the orientation of the measurement plane M (i.e., on the angle z'), and consequently, general for all the three radiointerferometers at simultaneous measurements of $R_{H\,MAX}$ by a single source. Note that the eccentricity and the orientation of the anisotropy ellipse depend essentially on the selection of the model of irregularities, as this follows from (12) and (13).

We shall determine the angle z' by the current horizontal coordinates of the source A, z and the azimuth $A_б$ and the angle of site of radiointerferometer's base 0. We shall convene, at the same time, to count the azimuth from South through West, as is customary in astronomy; we shall consider for the positive direction of the base that of its upper end (Fig. 2). From the two spherical triangles DFG and FGH, formed by the azimuthal circles of the base, the source and the plane M* and the cross section of the sphere by the plane M, we have

$$\sin z' = \sin z \operatorname{ctg} E, \tag{14}$$

$$\operatorname{ctg} E = (\sin z \operatorname{tg} \theta - \cos z \cos \Delta A) / \sin \Delta A, \tag{15}$$

where $\Delta A = A - A_б$. Resolving (15) relative to sin E and substituting the value thus found into (14), we shall obtain for sin z'

$$\sin z' = \frac{\sin z \cos \theta \sin \Delta A}{[1 - (\sin z \cos \theta \cos \Delta A + \cos z \sin \theta)^2]^{1/2}}.$$

For the computation of the azimuth A_d dimension at the point of encounter of the ray with the layer S we shall consider the two triangles (Fig.1) formed by the meridians of the point of observation and of the point S by the azimuthal circle of the source (arc a) and the azimuthal circles of the plane M at the point of observation (arc b) and at the point S (see Fig.1). Here 0 is the central projection on Earth of the center of the cross section circles by the plane M, of the Earth and the layer; φ is the latitude of the point of observation; A_s is the azimuth of the ray at the point S. Taking into account that at the point S the angle between the azimuthal circle of the plane M and the cross-section of the layer by this plane is a right angle, we shall write for A_d

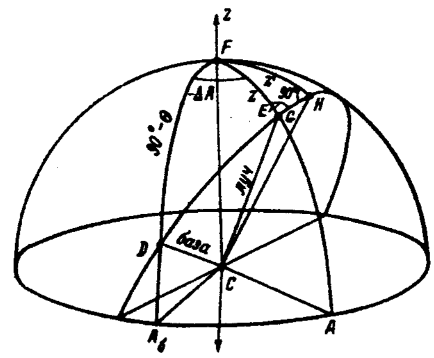

Fig. 2

$$A_d = A_s - B \pm 90°, \tag{16}$$

* We define as the azimuthal plane of the plane M the plane normal to M and passing through the zenith at the given point.

We find A_S from ΔCNB:

$$\operatorname{ctg} A_s = (\sin a \operatorname{tg} \psi + \cos a \cos A) \,/\, \sin A, \tag{17}$$

where

$$\sin a = \frac{l}{R+h} \sin z. \tag{18}$$

Substituting the value of l from (10 and (18), we shall obtain

$$\sin a = \frac{1}{K} \sin z \{ (K^2 - \sin^2 z)^{1/2} - \cos z]. \tag{19}$$

We shall find the angle B from the triangle OCB

$$\cos B = (\cos b - \cos c \cos a) \,/\, \sin c \sin a, \tag{20}$$

where

$$\cos b = \sin z'; \tag{21}$$

$$\sin c = \frac{r}{R+h} = \frac{1}{K} (K^2 - \sin^2 z')^{1/2}; \tag{22}$$

$$\cos c = \frac{1}{K} \sin z'. \tag{23}$$

Substituting (19), (21), (22), (23) and the value of $\cos \alpha$ computed in (19) into (20) and effecting simple transformations, we obtain

$$\cos B = \frac{\sin z'}{\sin z} \left(\frac{K^2 - \sin^2 z}{K^2 - \sin^2 z'} \right)^{1/2}. \tag{24}$$

T H E   E N D

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